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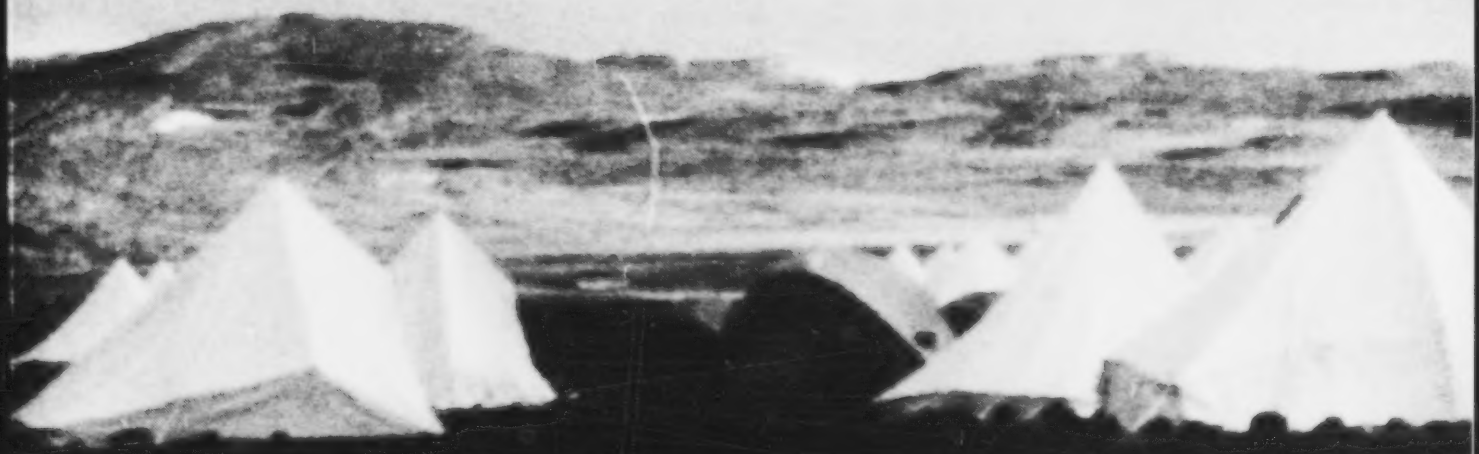

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Auriferous iron-formation in the upper Hayes River area, central mainland, Nunavut

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Hyde, D.J., Jenner, G.A., and Sherlock, R.L., 2002: Auriferous iron-formation in the upper Hayes River area, central mainland, Nunavut; Geological Survey of Canada, Current Research 2002-E7, 9 p.

Abstract: The Committee Bay greenstone belt, underlain by the largely underexplored Archean Prince Albert group, is prospective for many different styles of mineralization. This report focuses on iron-formation-hosted gold occurrences in the upper Hayes River area, southwestern portion of NTS 56-O near Walker Lake. In this area, gold is associated with sulphidized magnetite-silicate iron-formation and deformed sulphidic quartz veins, localized within a corridor of highly strained rocks. On the basis of deformation fabrics, sulphidation reactions and associated gold mineralization predate or are early within the development of the main composite transposition fabric ($S_2 \pm S_1$). The deformation event associated with the deposit is interpreted to have resulted from strain partitioning into the supracrustal sequence, possibly during development of the Walker Lake shear zone.

Résumé : La ceinture de roches vertes de Committee Bay pourrait renfermer des zones caractérisées par une gamme de styles de minéralisation. Elle repose sur le groupe archéen de Prince Albert, qui est en majeure partie sous-exploré. Le présent article porte essentiellement sur les venues aurifères dans les formations de fer situées dans la région du cours supérieur de la rivière Hayes, dans la section sud-ouest de la région cartographique 56-O du SNRC, près du lac Walker. L'or y est associé à des formations de fer à magnétite-silice sulfurées et à des filons de quartz sulfuré déformés qui gisent dans un corridor de roches profondément déformées. D'après la fabrique de déformation, la sulfuration et la minéralisation en or associée se sont produites avant ou peu après le début de la formation de la principale fabrique de transposition composite ($S_2 \pm S_1$). On présume que l'épisode de déformation associé au gisement résulterait d'une répartition des déformations dans la séquence supracrustale, probablement pendant la formation de la zone de cisaillement de Walker Lake.

INTRODUCTION

The Committee Bay belt is part of the north-central extension of an approximately 2000 km long belt of plutonic and supracrustal rocks that extends from northern Saskatchewan through the Woodburn Lake area to north-central Baffin Island (Fig. 1). Its supracrustal rocks, collectively referred to as the 'Prince Albert group', are prospective for different commodities and mineral deposit types, most notably gold associated with iron-formation and nickel-copper(± platinum-group elements) associated with ultramafic intrusions and komatiite. This report focuses on a series of iron-formation-hosted gold occurrences in the upper Hayes River area approximately 300 km northeast of Baker Lake, Nunavut (southwest NTS 56-O, northwest NTS 56 J; Fig. 1). The upper Hayes River area was selected for this study as it is the best exposed and most continuous of the iron-formation-hosted gold showings in the area.

Gold exploration has been conducted intermittently by Apex Geoscience Ltd. and its predecessors since the early 1990s. Much of their work is responsible for the discovery of numerous gold showings in the Committee Bay belt, including the upper Hayes River area. In the upper Hayes River area, Apex Geoscience Ltd. identified three showings and conducted surface mapping and sampling followed by ground and airborne geophysics and diamond drilling. Significant rock chip samples include 23.4 g Au/t at the Hayes showing, 12.1 g Au/t at the Antler showing, and 8.6 g Au/t from the Three Bluffs showing. Significant drill results include 21 g Au/t across 1 m, and 3.4 g Au/t across 15 m (R.J. Wyllie and J. Williamson, unpub. rept., 1996). Much of the exploration results in the upper Hayes River and elsewhere in the Prince Albert group have been compiled by Sherlock and Deyell (2002).

The purpose of this research is to compare the nature and timing of gold mineralization in the upper Hayes River area to similar styles of mineralization elsewhere in the Prince Albert and Woodburn Lake groups. This project forms part of a multidisciplinary effort by the Canada-Nunavut Geoscience Office (C-NGO), the Geological Survey of Canada (GSC), and university partners. It will form part of a M.Sc. thesis by the senior author at Memorial University.

REGIONAL GEOLOGY OF THE COMMITTEE BAY BELT

The earliest regional mapping in the Prince Albert group by Heywood (1961) delineated the extent of the supracrustal sequences. Schau (1982) further subdivided the supracrustal and intrusive rocks of the Prince Albert group. Jefferson and Schau (1992) and Chandler et al. (1993) produced mineral-resource assessment reports as background to the Wager Bay national park initiative (including the headwaters of the Brown River).

A joint C-NGO and GSC regional mapping program was initiated in 2000 in the Committee Bay area (NTS 56 K; Sandeman et al., 2001a, b); it highlighted the presence of three broad crustal domains: a central region of northeast-trending granite-greenstone belts, metaluminous granitoid

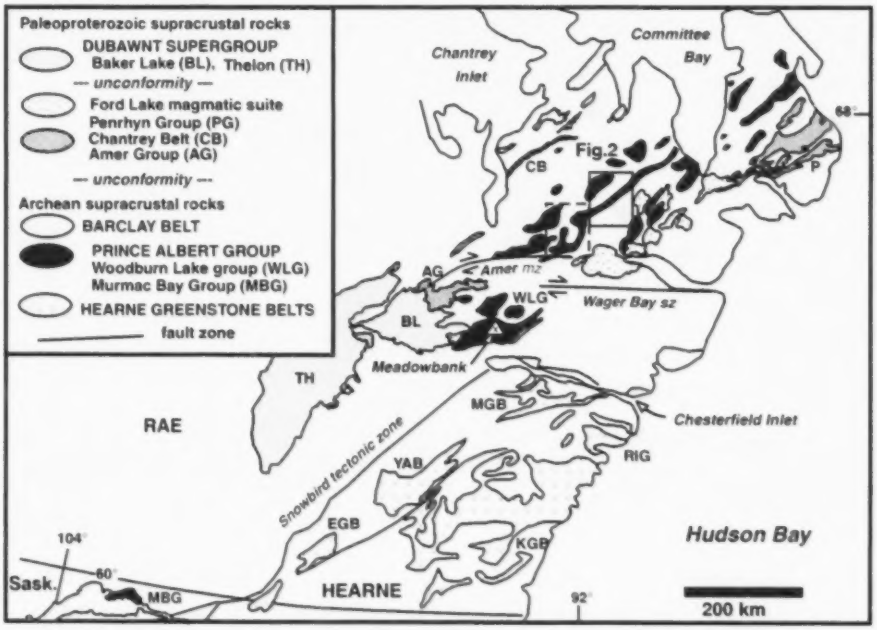


Figure 1. *Regional geology of the north-central western Churchill Province* (after *Sanborn-Barrie et al., 2002*). *The boxed area is shown in Figure 2.*

bodies in the south and southeast, and paragneiss and associated peraluminous and metaluminous granitoid bodies in the north. Sandeman et al. (2001a) described supracrustal rocks of the Laughland Lake area as being dominantly semipelite and psammite, iron-formation, and quartzite, with lesser spinifex-textured komatiite and rare basaltic and intermediate to felsic volcanic rocks.

Subsequent mapping in 2001 in the Walker Lake (NTS 56 J north half) and Arrowsmith River (NTS 56-O south half) map areas demonstrated the continuity of these three broad crustal domains (Skulski et al., 2002; Fig. 2). Within the central domain, Skulski et al. (2002) delineated four narrow supracrustal belts separated by lenticular plutonic bodies. From north to south, these are the dominantly metavolcanic northern and central Hayes River belts and the metasedimentary dominated Howling Wolf and Three Bluffs belts (Skulski et al., 2002). The southern metasedimentary dominated Three Bluffs belt contains the auriferous iron-formation and is the focus of this study.

In the Walker Lake–Arrowsmith River area, Sanborn-Barrie et al. (2002) distinguish two regionally significant deformation events in the central granite-greenstone belt. The earliest preserved fabric is a bedding-parallel foliation (S_0–S_1) that is rarely preserved in F_2 fold hinges. The dominant fabric recognized throughout the central domain is axial planar to regionally developed F_2 folds. In the hinge areas of the F_2 folds, weak S_2 fabrics are recognized that overprint the earlier S_1 foliations. In F_2 limbs, planar, penetrative fabrics are more intense and interpreted as a composite $S_2 \pm S_1$ fabric (Sanborn-Barrie et al., 2002). Subsequent deformation in the central granite-greenstone belt is marked by the development of shear zones, most notably the Northern shear zone (in the north; Fig. 2) and the Walker Lake shear zone, which affects the Three Bluffs metasedimentary belt (Johnstone et al., 2002; Sanborn-Barrie et al., 2002). The east-trending Walker Lake shear zone can be divided into spatially separated segments (Johnstone et al., 2002). The western segment, which transects map area NTS 56 K, is a heterogeneously deformed, 10 km wide corridor in which strain has been concentrated in protomylonitic bands several hundred metres wide. The eastern segment is a 40 km long dextral protomylonite to mylonite band that attains a maximum width of approximately 2 km (Johnstone et al., 2002). Strain localization in the eastern segment of the Walker Lake shear zone appears to be a function of competency contrast at the interface between supracrustal rocks and the southeastern Walker Lake plutonic complex. Johnstone et al. (2002) suggest that deformation along the Walker Lake shear zone is most likely associated with F_2 folding representing a progressive zone of concentrated D_2 strain.

The metamorphic grade of the central granite-greenstone domain varies from lower amphibolite facies in the southwest (upper Hayes River area) to middle amphibolite facies in the north and east. Most porphyroblastic minerals are typically pre- to synkinematic with respect to the dominant S_2 fabric with the exception of some postkinematic garnets, including those in pelitic rocks and garnet-bearing iron-formation in the upper Hayes River area (Sanborn-Barrie et al., 2002).

GEOLOGY OF THE UPPER HAYES RIVER AREA

The upper Hayes River area contains three separate gold showings in a discontinuously exposed linear belt of supracrustal rocks (Fig. 3). From west to east, these are the Hayes, Antler, and Three Bluffs showings. The supracrustal package in the upper Hayes River area is dominated by clastic sedimentary rocks with minor banded iron-formation, mafic to intermediate volcaniclastic rocks, and local mafic to ultramafic volcanic rocks. An extensive tonalite body as well as a smaller body of quartz diorite are intrusive into the supracrustal rocks. White-weathering quartz-feldspar-porphyritic intrusive units were observed in the supracrustal rocks, but not in tonalite or quartz diorite. Pink to white-pink pegmatite dykes intrude all rock types. The descriptions provided below are from an examination of outcrop and drill core.

Clastic metasedimentary rocks

Clastic metasedimentary rocks include biotite semipelite, minor biotite-muscovite pelite, and biotite psammite. The pelitic to semipelitic portions of these rocks typically consist of fine-grained biotite, quartz with minor plagioclase, and trace apatite, often with centimetre-scale garnet and local cordierite porphyroblasts (Fig. 4). Quartz grains exhibit an annealed texture and undulose extinction. The field distinction between semipelite and psammite is based on biotite content. Cordierite porphyroblasts are found exclusively in pelitic to semipelitic rocks in the structural footwall and hanging wall of the auriferous iron-formation.

Iron-formation

At the Three Bluffs prospect (Fig. 3), iron-formation is discontinuously exposed in low- weathering parallel ridges, interlayered with pelitic sedimentary rocks. The mineralized iron-formation is about 20 m thick and can be traced along strike for several hundred metres. The iron-formation is dominated by millimetre- to centimetre-scale layers of magnetite and quartz (Fig. 5) with garnet- and amphibole-bearing intervals that are typically 1 to 10 cm thick, interpreted as interbeds of silicate-facies iron-formation. Several zones approximately 0.5 m thick of fine-grained siliciclastic sedimentary rocks occur interlayered within the iron-formation. The contact between iron-formation and metasedimentary rocks is gradational, as observed in drill core, with increasing amounts of fine-grained siliciclastic sedimentary rocks into both the footwall and hanging wall of the iron-formation. At the Antler and Hayes showings, garnet is absent and the iron-formation occurs as low-weathering, laterally extensive units, typically 0.5 to 1 m thick interbedded with similar siliciclastic sedimentary rocks.

Intermediate, mafic, and ultramafic volcanic rocks

Volcanic rocks are subordinate in the upper Hayes River area. An outcrop of intermediate volcanic rocks in the eastern part of the map area (Fig. 3), is fine grained and weathers a

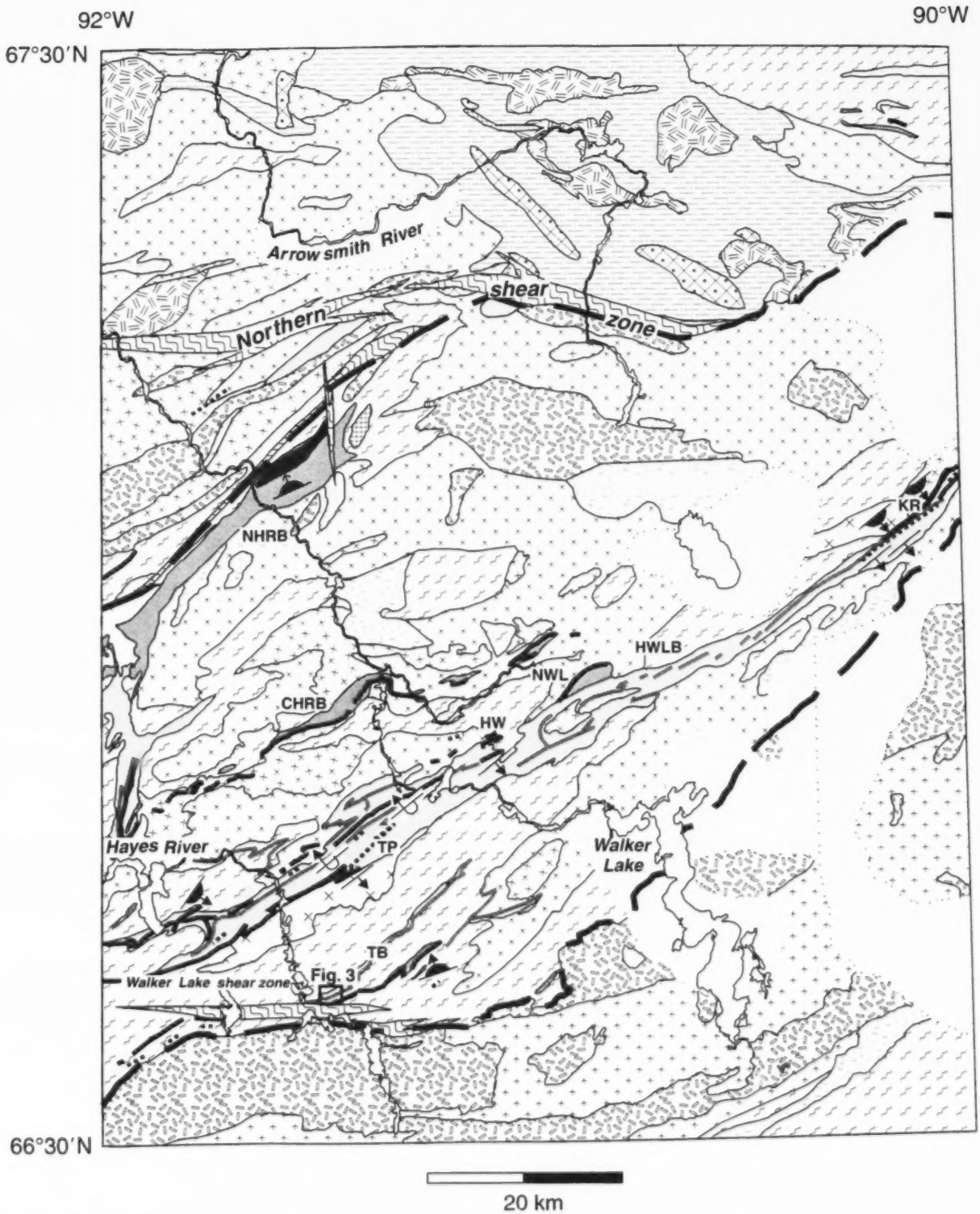
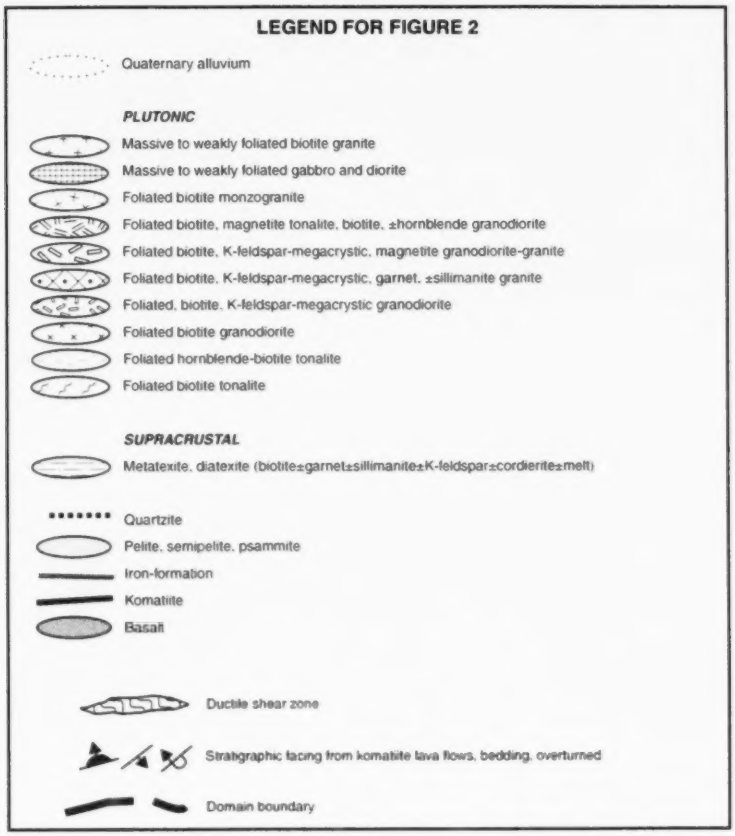


Figure 2. *Simplified geological map of the Walker Lake–Arrowsmith River area, Nunavut, NTS 56 J (north half) and NTS 56-O (south half)* (modified from *Sanborn-Barrie et al., 2002*). *Inset of study area (Fig. 3) is shown in lower left corner.*



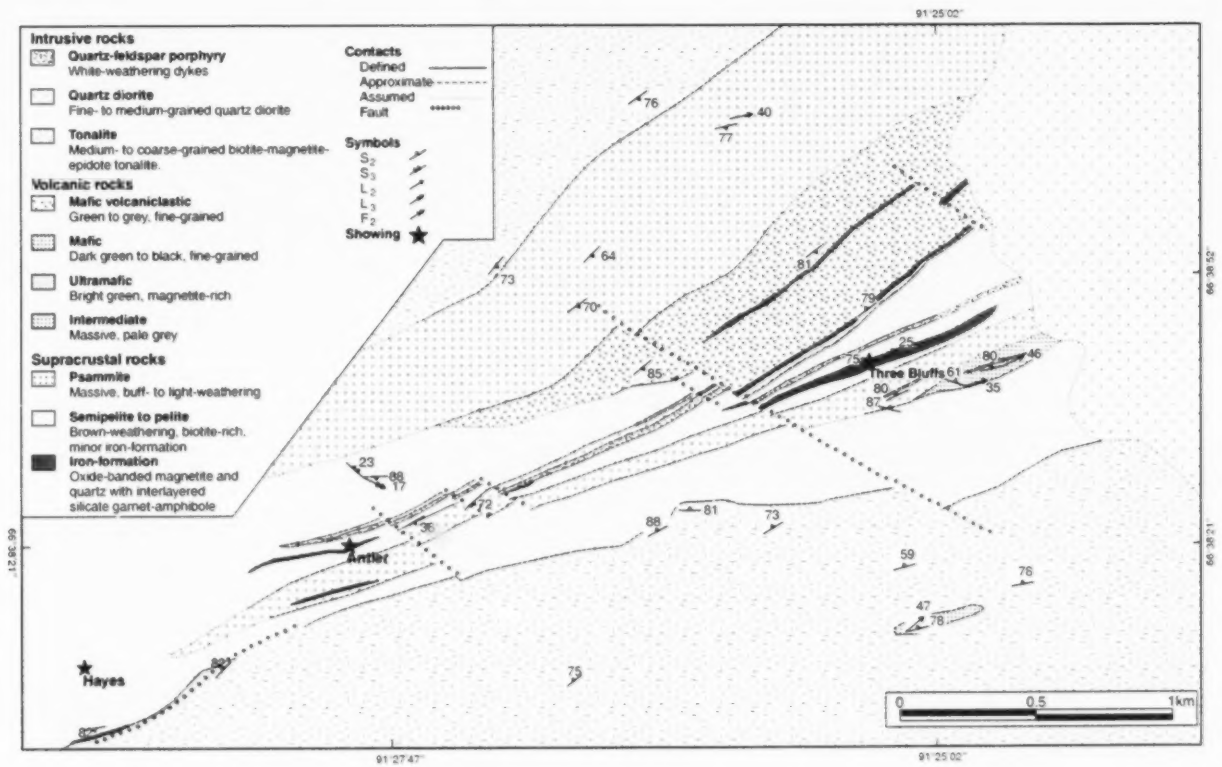


Figure 3. Geology of the upper Hayes River area.

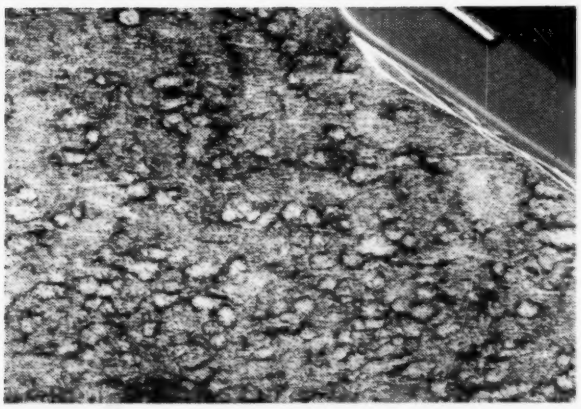


Figure 4. *Centimetre-scale cordierite (white) and garnet (dark) porphyroblasts in semipelitic metasedimentary rocks near mineralized iron-formation at Three Bluffs. Knife measures 2 cm.*

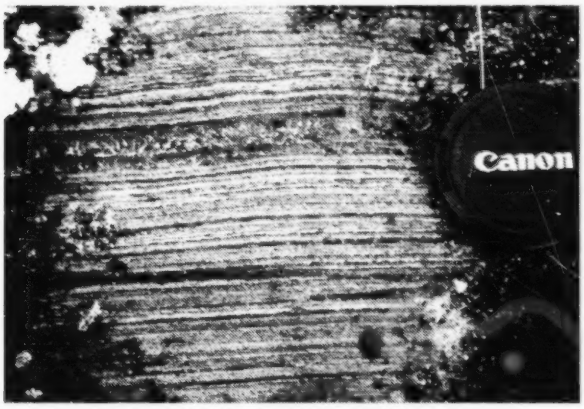


Figure 5. *Thinly (<0.3 cm) laminated layers of magnetite and quartz in oxide-facies iron-formation, showing primary compositional layering. Lens cap measures 5 cm.*

distinctive pale grey. Similar rocks were traced along strike for several hundred metres from the main outcrop. Mafic volcanic rocks are observed at only one location (Fig. 3), forming an outcrop about 20 m wide that cannot be traced along strike. These amphibolitized rocks are dark green to black, and primary volcanic textures are absent.

Ultramafic rocks have been observed at several locations (Fig. 3). Several hundred metres north of the Three Bluffs showing, strongly foliated, talc-anthophyllite schist is in contact with iron-formation. This unit weathers a pale green to grey and contains locally abundant magnesite veins. In the southwestern portion of the map area, an interval of ultramafic rocks with an average thickness of about 5 m is exposed for approximately 300 m along strike. These rocks are more massive than those exposed in the vicinity of the Three Bluffs prospect; they have a conformable hanging-wall contact with an iron-formation about 1 m wide and a faulted footwall contact with tonalite. Although primary volcanic textures were not preserved, the rocks exhibit about 1 m wide rhythmic discolouration banding from pale green to brown, typical of ultramafic volcanic rocks of the Prince Albert group.

Volcaniclastic rocks

Two types of volcaniclastic rocks have been identified. Fine- to medium-grained, grey-green-weathering rocks with abundant chlorite and minor biotite exhibit a granular clastic texture and are interpreted as mafic tuff. The second type of volcaniclastic rocks is seen in one small outcrop and consists of a clast-supported fragmental unit about 1 m thick. Fragments appear to be intermediate in composition and are possibly silicified. Fragments are structurally elongated and typically 1 to 2 cm wide by 10 cm long.

Intrusive rocks

Supracrustal rocks of the Three Bluffs belt are bound to the north and south by medium-grained, moderately foliated (S_2), biotite-, epidote-, and magnetite-bearing tonalite (Fig. 3). In the south, the contact between the supracrustal rocks of the upper Hayes River area and the tonalite is characterized by brittle faults. In the north, the boundary is gradational, with xenoliths of supracrustal rock occurring within the tonalite and sheets of tonalite occurring in the supracrustal rocks, indicating an intrusive relationship.

A poorly exposed body of fine- to medium-grained hornblende-quartz diorite truncates the supracrustal rocks at the eastern edge of the Three Bluffs map area. The quartz diorite locally contains a weak southwest-trending fabric (S_2), but is typically massive and undeformed. Quartz diorite dykes are seen throughout the area and are observed in drill core.

Two distinct types of dykes are recognized. Foliated fine-grained, quartz-feldspar-porphyritic dykes range from 0.5 to 10 m wide, are oriented parallel to the main northeast fabric, and are laterally continuous for several hundred metres. Quartz phenocrysts exhibit a recrystallized texture and are typically elongate up to 0.5 cm long. As these dykes appear to have undergone the same deformation as the host supracrustal sequence, they are interpreted to be relatively early and may represent synvolcanic bodies. The second type of dyke consists of pink-white, coarse-grained syenogranite to monzogranite pegmatite that cuts the main foliation (S_2) and is locally folded.

STRUCTURE

The main fabric observed in the upper Hayes River area is a strong, northeast- to southwest-striking and steeply northwest- to southeast-dipping, penetrative foliation (S_2) that is interpreted to be a composite transposition foliation (Sanborn-Barrie et al., 2002). This fabric is axial planar to northeast-plunging folds (F_2; Fig. 6) and is defined by aligned biotite in

Figure 6. *Upright, moderately northeast-plunging, tight to isoclinal folds of sulphidized iron-formation at Three Bluffs (facing southwest). Lens cap measures 5 cm.*

both the supracrustal and deformed plutonic rocks. The regional S_1 foliation (Johnstone et al., 2002; Sanborn-Barrie et al. 2002) has not been observed in the upper Hayes River area. The S_2 fabrics, which are bedding-parallel, show a dip reversal across the upper Hayes River iron-formation (Fig. 3), which suggests an F_2 fold with the iron-formation occupying the core of the fold. The strata in the upper Hayes River area are very planar, interpreted to be the result of rotation and attenuation during D_2 deformation that has formed the dominant composite transposition fabric.

Locally, decimetre-scale chevron folds and associated spaced cleavage define a subsequent phase of deformation in the region (D_3). The chevron folds plunge shallowly to moderately to the southeast and the spaced cleavage is typically oriented north-northwest, dipping steeply to the northeast. As observed in thin section, S_3 is defined by relatively coarse biotite aligned at an acute angle to finer grained biotite.

METAMORPHISM

The metamorphic mineral assemblage consists of biotite±cordierite and garnet in semipelite and garnet+amphibole in silicate-facies iron-formation, suggesting lower middle amphibolite facies metamorphic conditions. Cordierite forms poikiloblasts with abundant inclusions of biotite and quartz (Fig. 4) and is found exclusively within the semipelitic to pelitic rocks that enclose the auriferous iron-formation. Garnet occurs in pelitic to semipelitic rocks throughout the upper Hayes River area in centimetre-scale pelitic bands in psammite. Garnet is also abundant in silicate-rich iron-formation. Garnet typically forms euhedral crystals with minor quartz inclusions, and truncates biotite foliation in both pelitic layers and silicate-facies iron-formation. Coarse hornblende occurs with garnet and biotite in silicate-rich intervals, interlayered with oxide-facies iron-formation, and rarely in semipelitic rocks immediately surrounding auriferous iron-formation at the Three Bluffs showing. Fine-grained cummingtonite, grunerite, hornblende, and minor anthophyllite occur interstitially within magnetite bands throughout units of oxide-facies iron-formation.

The mineral assemblages at Three Bluffs suggest at least two distinct phases of mineral growth. The main S_2 fabric, as defined by aligned biotite, wraps around cordierite poikiloblasts. The cordierite poikiloblasts are flattened and aligned in the direction of S_2 and contain abundant biotite and quartz inclusions, which are also aligned in the direction of S_2, suggesting that cordierite formed prior to, or early within, D_2. In contrast, coarse subhedral to euhedral, centimetre-scale garnet and amphibole porphyroblasts in silicate-facies iron-formation overgrow S_2, indicating formation during a subsequent post-tectonic event (M_2).

MINERALIZATION

The main gold-bearing zone at the Three Bluffs showing forms a linear trend, which is approximately on strike with the Antler and Hayes showings (Fig. 3). It is uncertain whether or not the iron-formation at each of the showings is a stratigraphic equivalent, as the parallelism of the zones is largely due to strong transposition of the strata. Sulphide minerals in decreasing order of abundance include pyrrhotite, pyrite, arsenopyrite, and chalcopyrite. Sulphides are typically associated with zones of pervasive silicification. R.J. Wyllie and J. Williamson (unpub. rept., 1996) report minor amounts of visible gold in drill core and suggest that gold is associated with zones of pervasive silicification.

At least two types of quartz veins occur in the auriferous iron-formation at the Three Bluffs showing. The earliest are blue-grey veins, which are disrupted, boudinaged, and elongated in the same orientation as the F_2 fold axes. These veins typically contain the same sulphide assemblage as the auriferous iron-formation and show a strong spatial relationship with the mineralization. The second generation of quartz veins cuts compositional layering and the S_2 foliation. These veins are typically less than 0.5 cm wide and postdate gold and sulphide introduction. Sulphides and blue-grey quartz veins

were not recognized in the two large barren iron-formation outcrops that parallel the Three Bluffs showing (Fig. 3); however, late crosscutting quartz veins are also present.

Pyrrhotite is the dominant sulphide in the upper Hayes River area (Fig. 7). It occurs as semimassive pods in the necks of boudinaged quartz veins, as disseminated to semimassive concentrations in pervasively silicified zones, and as millimetre-scale parallel bands that mimic primary compositional layering. Intervals with higher concentrations of pyrrhotite are typically magnetite-poor and silicified. Triple-point grain boundaries are common in monomineralic masses of pyrrhotite, suggesting that metamorphic recrystallization has occurred. It is also common to see pyrrhotite concentrated along grain boundaries and along cleavage planes of silicate minerals.

Pyrite typically forms millimetre-scale euhedral grains, in layers concordant with compositional layering, usually associated with other sulphides. It is also seen in veinlets, which crosscut compositional layering, and fills open cavities. Arsenopyrite is commonly observed as tabular, millimetre-scale, euhedral crystals, typically occurring in zones of magnetite-rich oxide-facies iron-formation. The magnetite+arsenopyrite zones are typically devoid of pyrrhotite; however, rare arsenopyrite is intimately associated with semimassive pyrrhotite. Chalcopyrite generally forms millimetre-scale veinlets, discordant to compositional layering. At a microscopic scale, chalcopyrite is often observed in the apex of pyrrhotite triple-point junctions and partially rimming pyrite grains in masses of pyrrhotite.

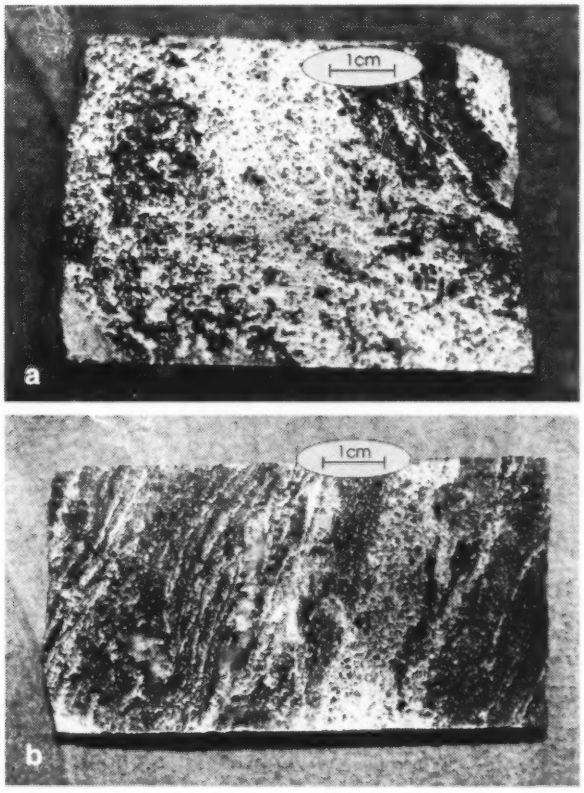


***Figure 7. a)** Semimassive pyrrhotite (light) associated with pervasively silicified zone in drill core. **b)** Finely laminated pyrrhotite and magnetite cut by quartz veins with a layer of semimassive pyrrhotite (light) and associated hornblende (black).*

DISCUSSION AND SUMMARY

Clastic metasedimentary rocks dominate the supracrustal package in the upper Hayes River area. Interlayered within the metasedimentary rocks are iron-formation, mafic to intermediate volcanic and volcaniclastic rocks, as well as mafic to ultramafic volcanic rocks. The supracrustal sequence is intruded by an extensive tonalite body, a smaller quartz diorite body, and a series of volumetrically minor granitic dykes and possible subvolcanic felsic intrusions.

Two phases of deformation have been recognized. Tectonic fabrics include a strong northeast-striking foliation that is oriented axial planar to moderate northeast-plunging F_2 folds, and overprinted by a weak to moderately developed northwest-southeast-spaced crenulation cleavage (S_3) and associated minor folds. The gold deposits are enclosed within a corridor of concentrated D_2 strain, which is interpreted to have resulted from strain partitioning into the supracrustal sequence adjacent to felsic intrusive bodies due to mechanical contrasts between rock types. This corridor of high strain likely developed progressively during the D_2 event and may be a splay of the Walker Lake shear zone.

Two phases of metamorphism are also recognized. The earliest (M_1) resulted in the formation of a biotite foliation and cordierite poikiloblasts in pelitic to semipelitic rocks and is considered to have occurred prior to or early within D_2. Later post-tectonic metamorphism (M_2) gave rise to post-kinematic garnet in pelitic rocks and garnet and hornblende in iron-formation.

Pyrrhotite is the dominant sulphide mineral in the upper Hayes River area. It occurs as semimassive concentrations in highly silicified zones, in the necks of boudinaged blue-grey quartz veins, and as discreet, millimetre-scale, layer-concordant bands. Textural relationships indicate that pyrrhotite is not a primary constituent of the iron-formation, but has replaced magnetite through sulphidation reactions and is associated with the distinctive blue quartz-sulphide veinlets. Gold is located in zones of pervasive silicification and sulphidation and is inferred to have been introduced during these events.

Cordierite is restricted to a zone about 10 m wide within pelitic to semipelitic rocks that enclose the auriferous iron-formation. This distribution may reflect the effect of hydrothermal alteration related to gold mineralization. It is unlikely to be a bulk composition effect since similar rocks at similar metamorphic grade in other areas of the belt do not contain cordierite. Yardley (1989) suggests that cordierite can form in pelitic rocks as a result of the liberation of Fe during sulphidation reactions and may be related to a hydrothermal alteration related to sulphidation and silificiation. Consequently, cordierite development in pelitic rocks around

the upper Hayes River may be an effective exploration criterion to outline zones of hydrothermal alteration in otherwise visibly unaltered metasedimentary rocks.

The timing of gold introduction is uncertain, but some inferences can be made. On the basis of textural relationships, gold introduction appears to be related to deformed and boudinaged sulphidic blue quartz veins that have been deformed in D_2-related fabrics, suggesting pre- or early D_2 timing. If cordierite development is related to hydrothermal alteration, then pre- or early D_2 timing is also suggested. The corridor of high strain in which the upper Hayes River showing is localized is a D_2 fabric. By spatial association it is likely that gold introduction is related to this high-strain corridor. The mineralized iron-formation is deformed by the D_2 event; however, mineralization may have occurred early within a progressive D_2 event, concentrated by mechanical contrasts in the host rocks.

A number of similarities exist between auriferous iron-formation in the upper Hayes River and other such units in the Woodburn Lake group, such as the Meadowbank deposit (Sherlock et al., 2000). The overall mineralogy of the deposits is similar with the dominance of pyrrhotite replacing magnetite-facies iron-formation. The metamorphic grade is higher (lower amphibolite facies) in the upper Hayes River area than in the Meadowbank area (upper greenschist facies), with consequent differences in silicate mineral assemblages. In the Woodburn Lake group, the auriferous iron-formation is localized in regions where supracrustal belts are narrowest and strain has been partitioned into them as a result of mechanical contrasts (Sherlock et al., 2001a, b). In the upper Hayes River area, gold and sulphide introduction is suggested to have occurred relatively early in the development of the dominant D_2 event, whereas at the Meadowbank deposit, mineralization is interpreted to have been introduced at the culmination of a D_2 progressive event. Critical to the localization of these deposits is the development of a structural setting in which strain is partitioned into the reactive iron-formation and localized dilational settings that allow for sulphidization of the iron-formation and introduction of gold.

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